Mesoscale Convective System life cycle : TOA/BOA fluxes and profiles from CERES/MODIS/CloudSat

D. Bouniol[1], E. Poan[1], R. Roca[2], B. Rouquié[2], T. Fiolleau[3], C. Rio[4]

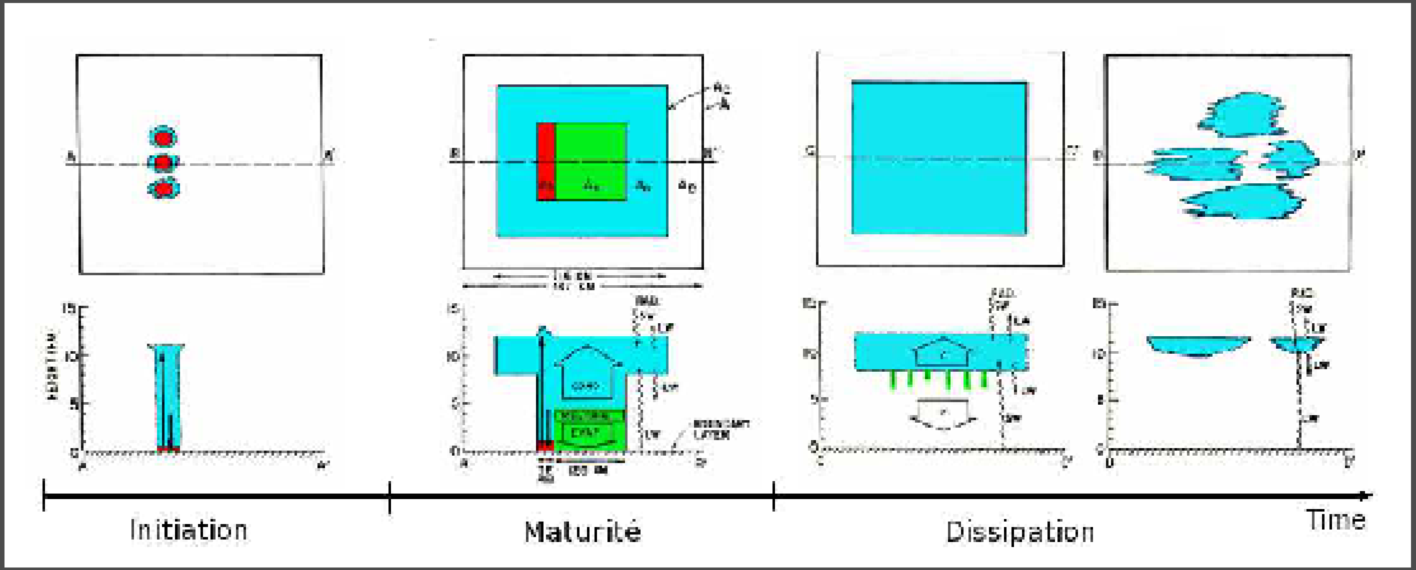
[1] GAME-GAME, CNRS/Météo-France, Toulouse
[2] LEGOS, CNRS, Toulouse
[3] CEMADEN, Cachoeira Paulista, Brazil
[4] LMD, CNRS, Paris

Joint CERES-GERB and SCARAB Earth Radiation Budget Workshop
7-10 october 2014 - Toulouse

Motivations :

MCSs are the major source of rain in the Tropics, however they also inject at mid to high altitude large quantity of ice that may persist several hours after rain has ceased.
MCSs can interact with the dynamical circulation through latent and radiative heating profiles

Importance of the MCS Life cycle / various MCS parts :



Houze, 1982

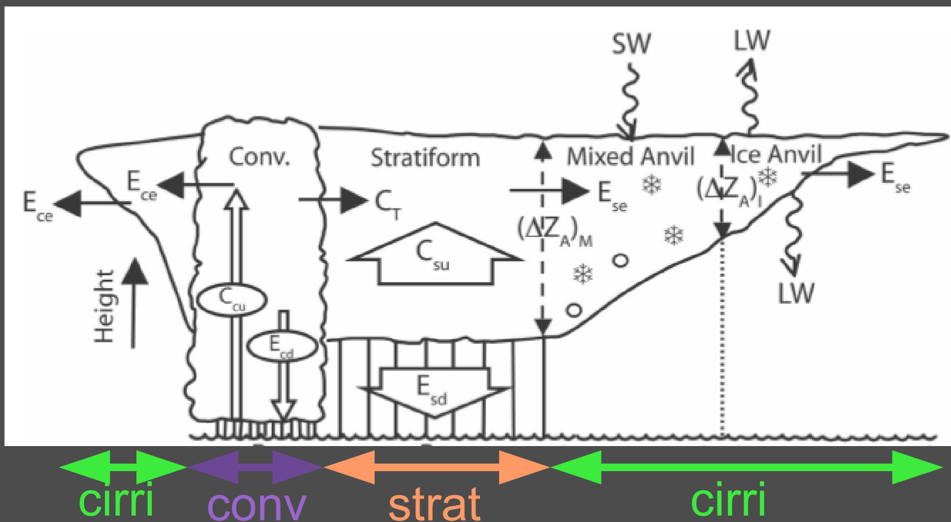
The life time of MCS anvil clouds + its size make its radiative impact non negligible.

Better understand what are the microphysical processes involved in the MCS life cycle
- to better understand their radiative impact at BOA and TOA
- to better understand their latent and radiative heating profiles
- to improve their representation and associated effects within GCM

Make use of the A-Train and geostationnary data sets

3 parts within MCS :

Convective/stratiform/non precipitating anvils : physical processes (in particular in term of dynamics) are intrinsequely different between the various parts



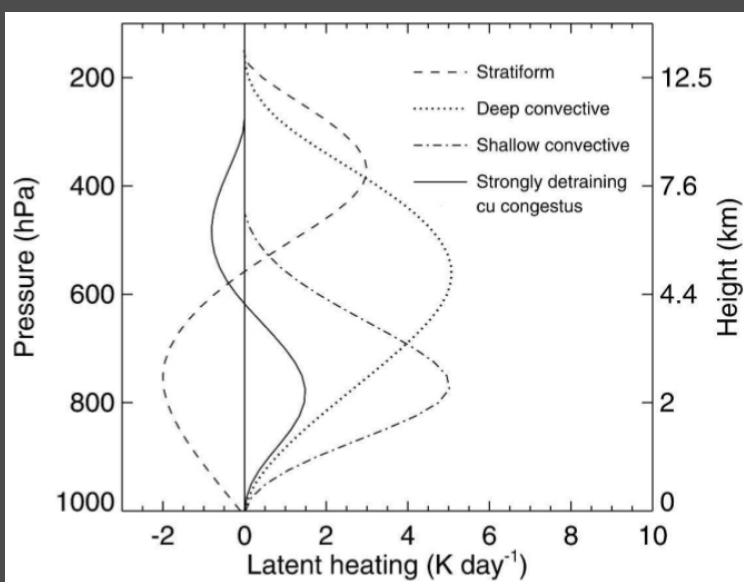
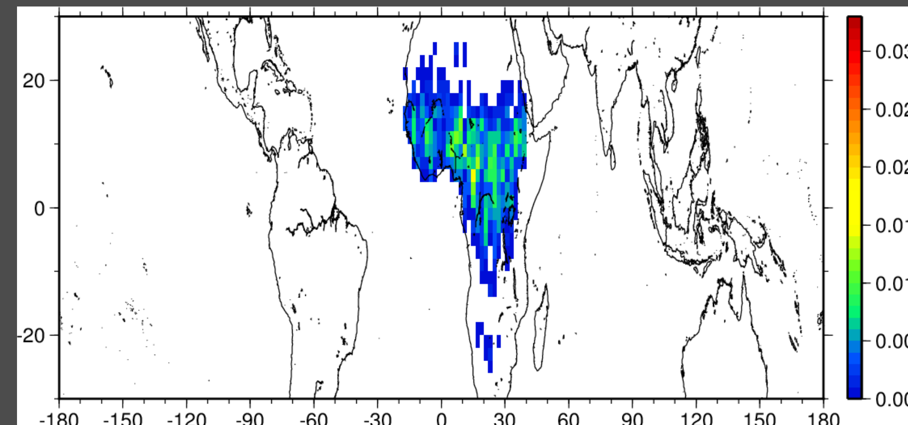


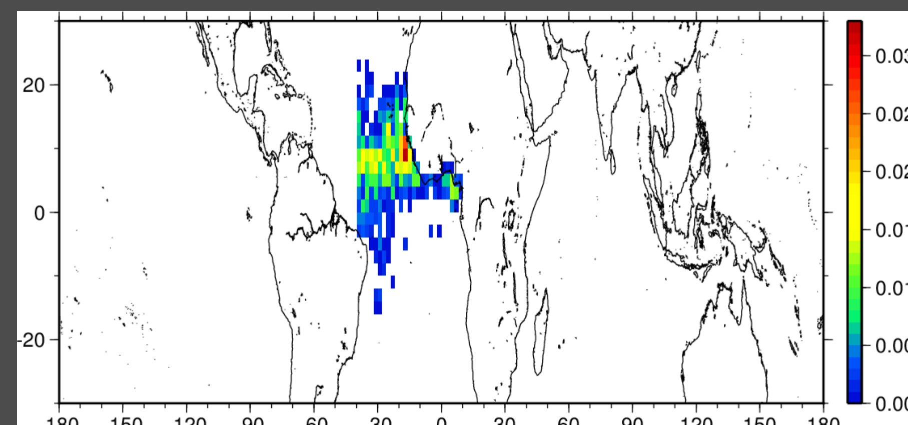
FIG. 1. Idealized latent heating profiles for different precipitating cloud types.

Schumacher et al (2007)

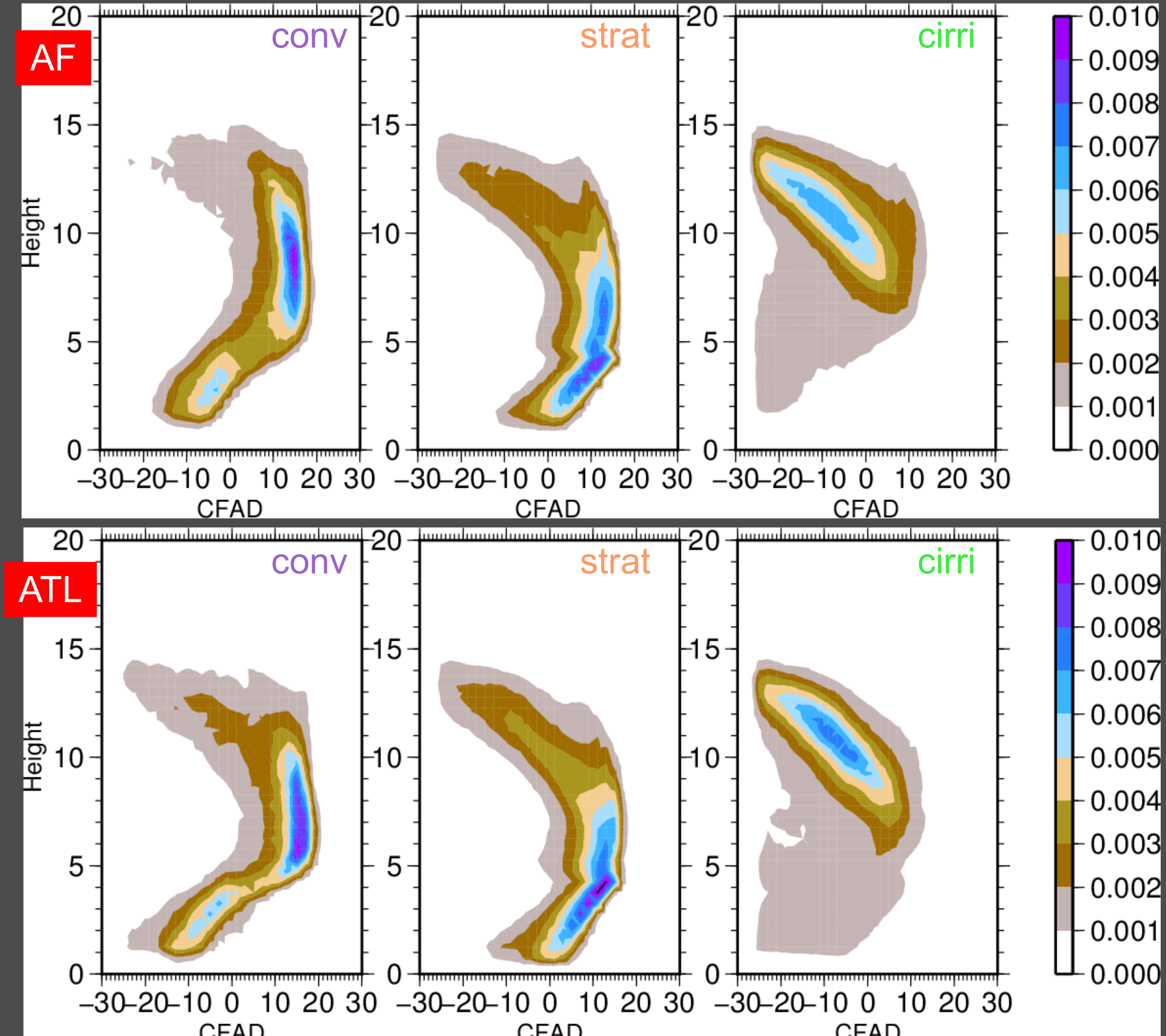
2 geographical areas :

Monsoon period for West Africa (AF) and adjacent Atlantic ocean (ATL)





CFAD of reflectivity without LifeStep : a static view...



Results similar as former studies :
Cetrone & Houze 2009
Yuan et al 2011
...

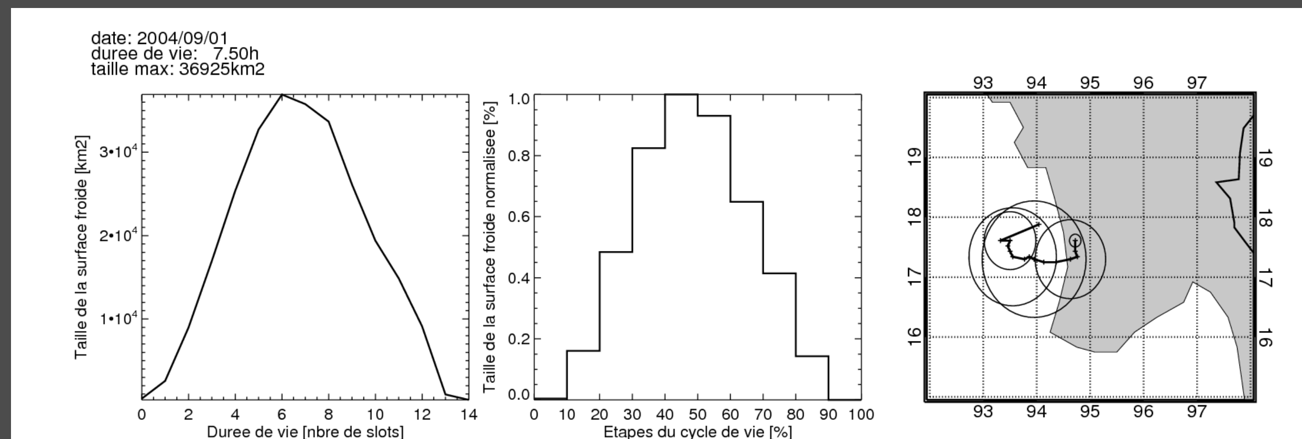
Conv : large value of Z (! Mie effect), but lower altitude for ATL
Strat : lower value of Z, ~ bi-modal (decrease + detrainement)
Cirri : lower value of Z, decrease with altitude (aggregation, less water content at cloud top)

Distribution of Z and its statistical parameters allow to infer microphysical properties within the life cycle

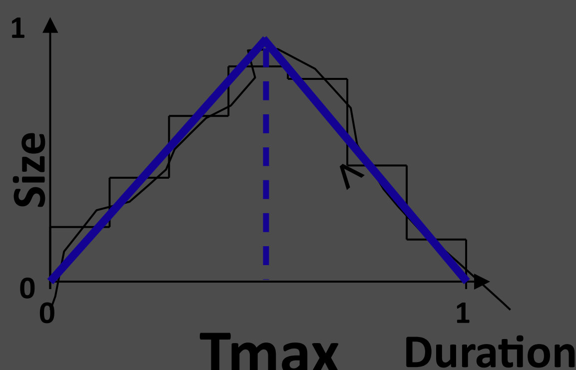
Composite along the MCS life cycle : discretrization in 10 steps

Polar orbiting satellites (A-Train) do not allow to document MCS life cycle => use of geostationnary temporal sampling + detection and following of MCS by a tracking algorithm : TOOCAN (Fiolleau & Roca 2013, Fiolleau 2010)

Illustration of the normalisation process



Linear Growth and Decay model (LGD)



Classification of the MCS

MCS Lifetime > 5h	
Population	Cold cloudiness
76%	98,5%

MCS describing only one maximum along their life cycle	
Population	Cold cloudiness
76%	77%

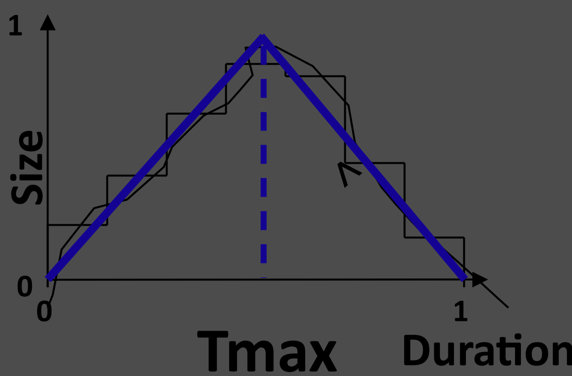
Two thirds of the MCS describe a symetric evolution of their surface

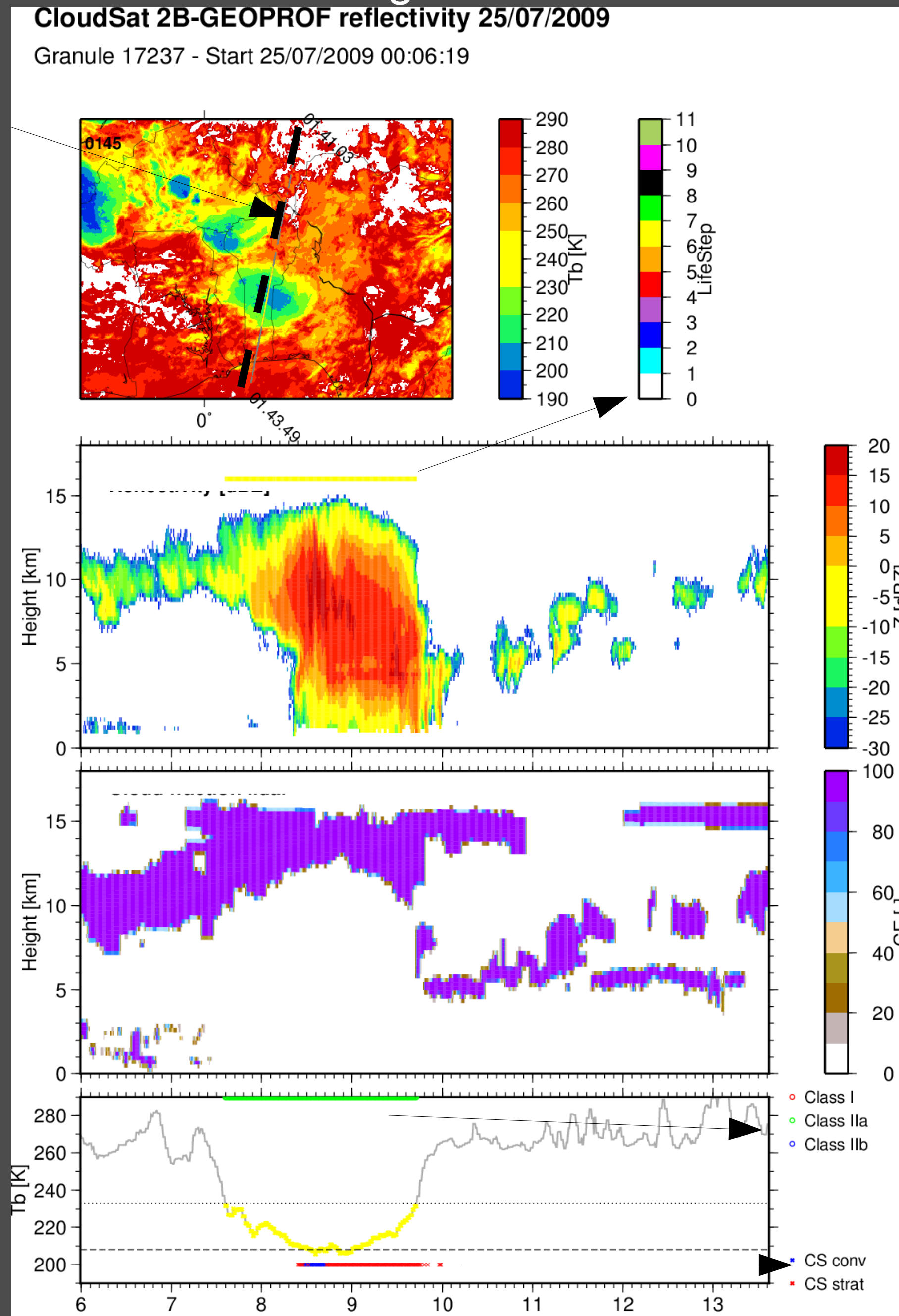
Composite along the MCS life : 10 steps and 3 regions

CloudSat projected within the tracking algorithm

CloudSat track

Linear Growth and Decay model (LGD)





TOOCAN + A-Train cross-points
- TOOCAN class (2a)
- TOOCAN Life Step
- CloudSat conv/strat flag (2C-PRECIP-COLUMN)

Composited properties

Macrophysics
CloudSat + CALIPSO (2B-GEOPROF-LIDAR)

Microphysics
CloudSat (2B-GEOPROF)

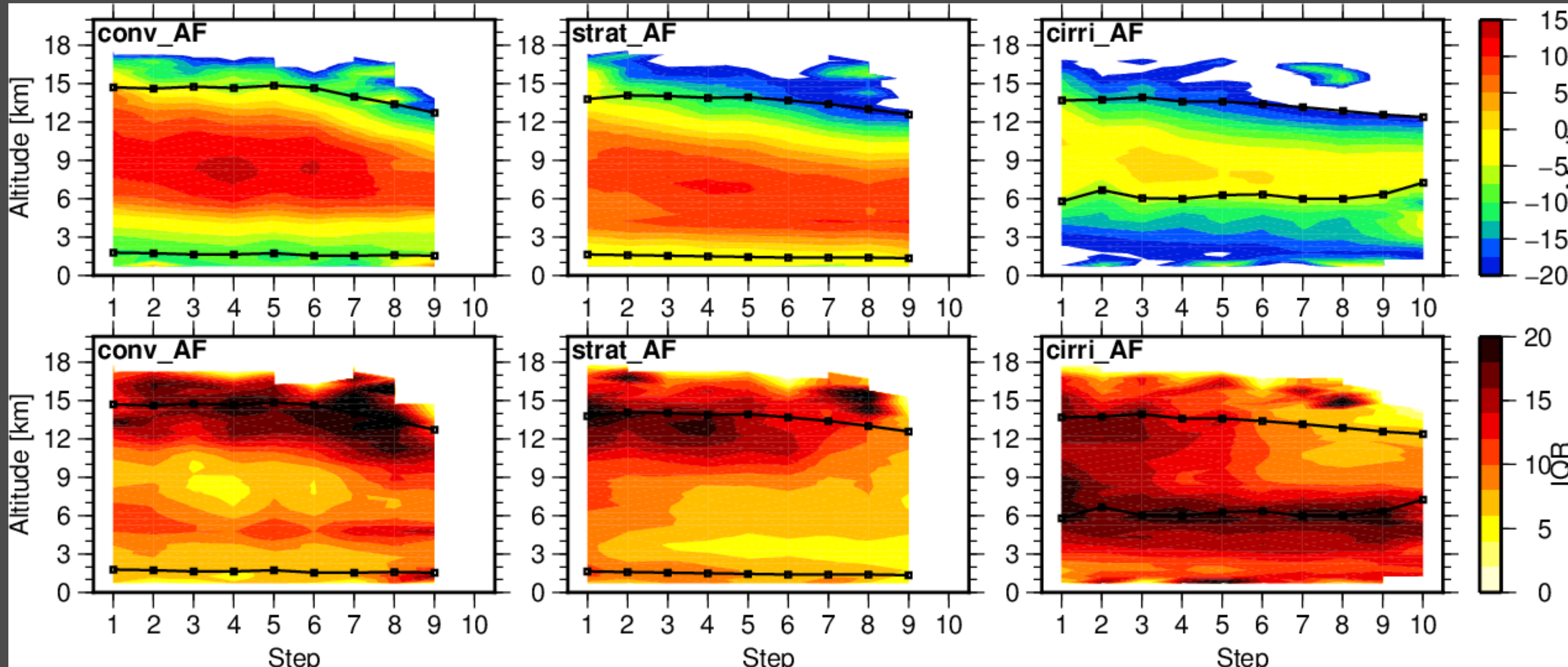
TOA/BOA radiative fluxes
CloudSat-CALIPSO (2B-FLXHR-LIDAR)
CERES-CloudSat-CALIPSO-MODIS (CERES-CCCM)

Radiative heating rate profile
CloudSat-CALIPSO (2B-FLXHR-LIDAR)

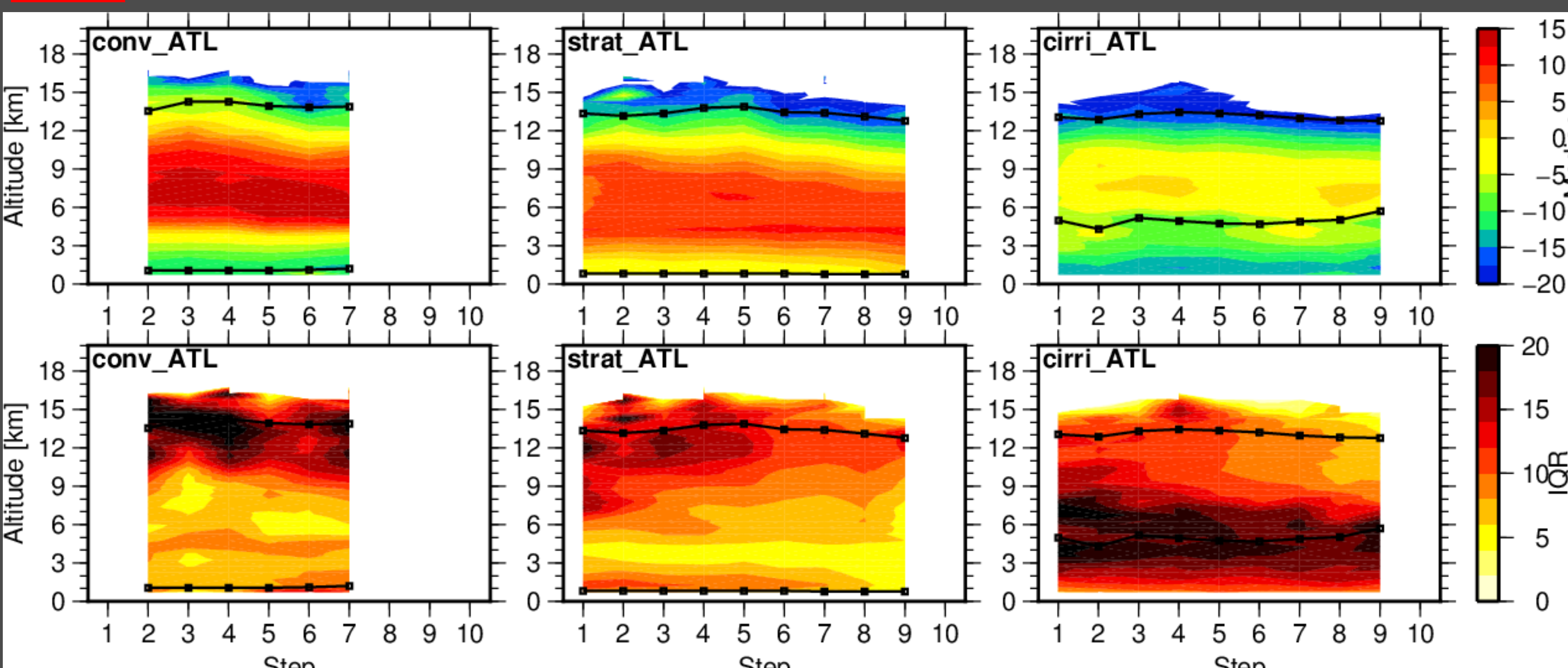
CFAD of reflectivity : inference of microphysical processes

AF

- Larger value of Z in conv/strat/cirri and at the beginning of the life cycle
- During life cycle : IQR increases for conv but decreases in the anvil

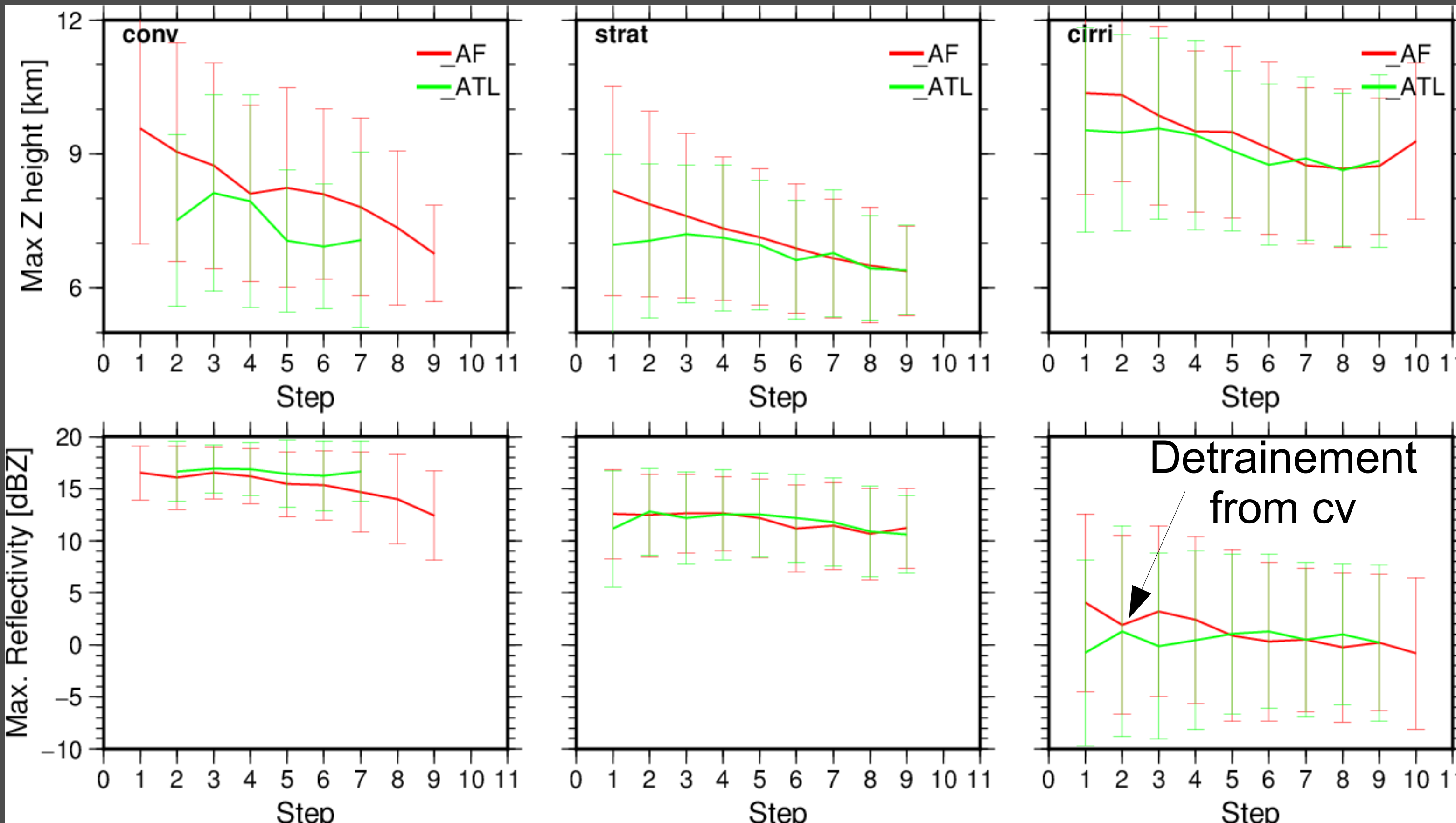


ATL



Larger vertical extend for AF
More constant values for ATL/AF
=> faster decreases of cv intensity
Same for stratiform rain

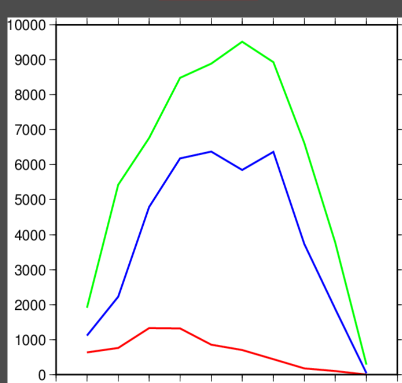
Convection features between the two regions



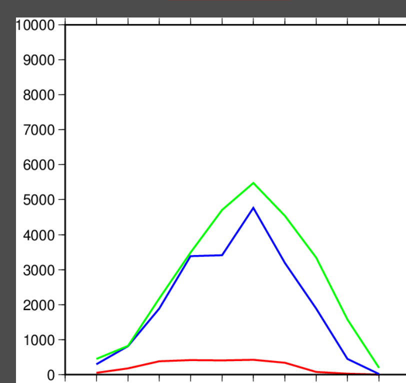
Proxy of convection intensity = alt max of the Z max

In proportion : larger fraction of stratiform profiles over ATL wrt AF

AF

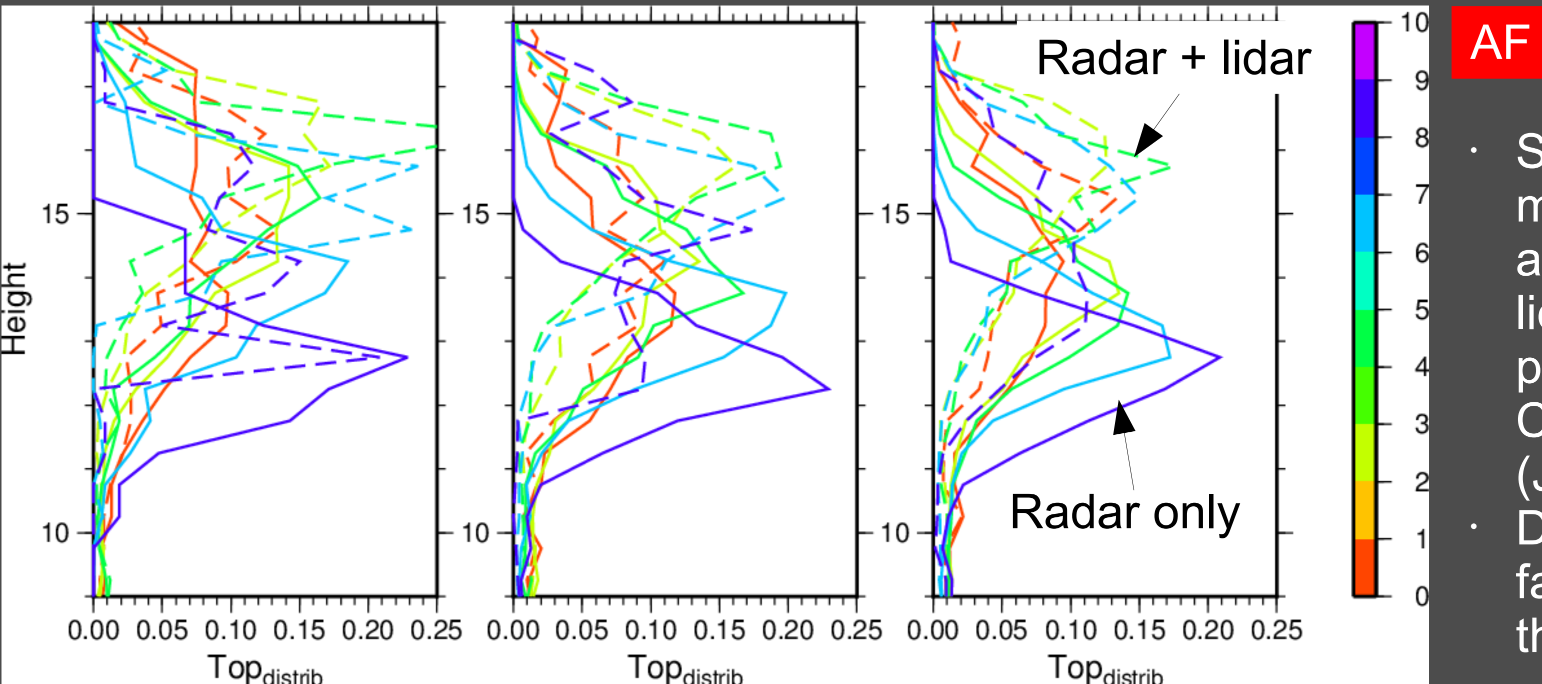


ATL



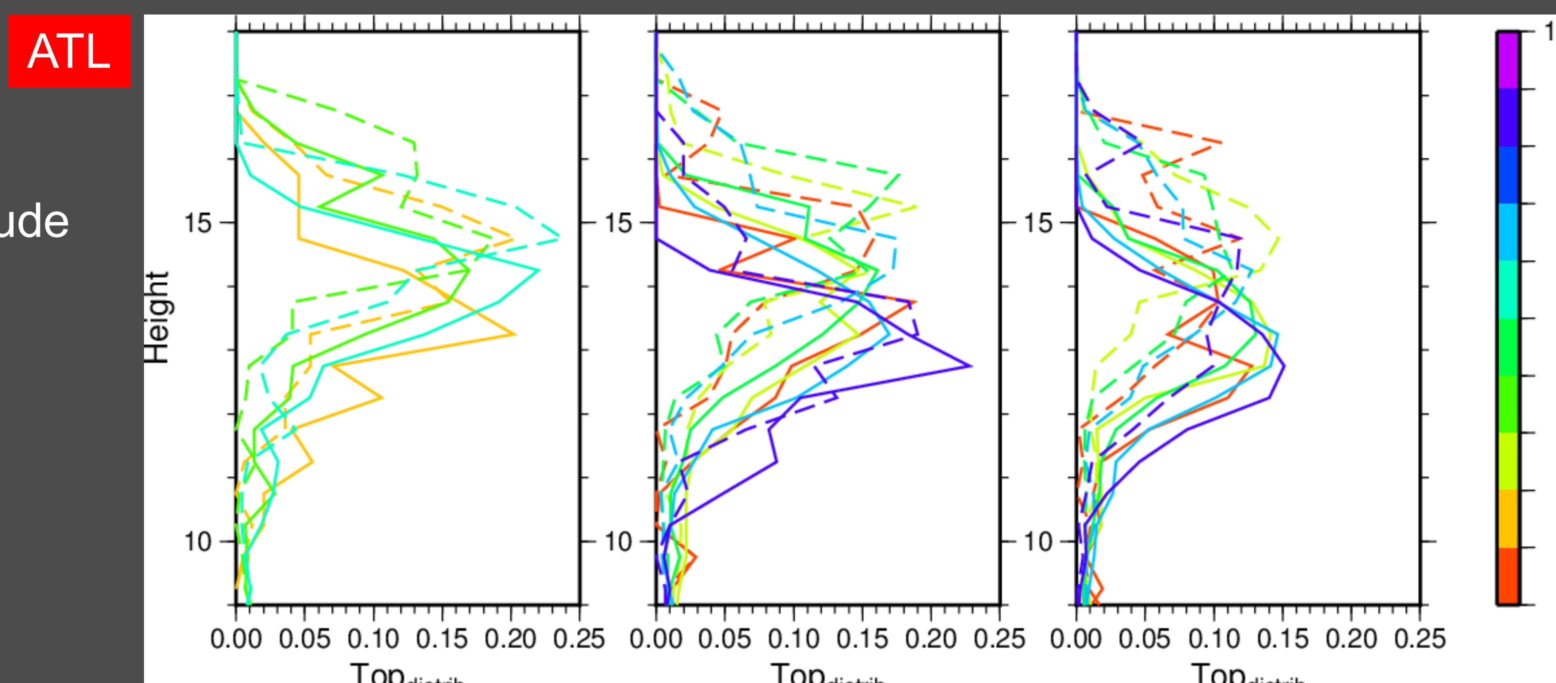
Convective
Stratiform
Non precipitating anvil

Macrophysical properties



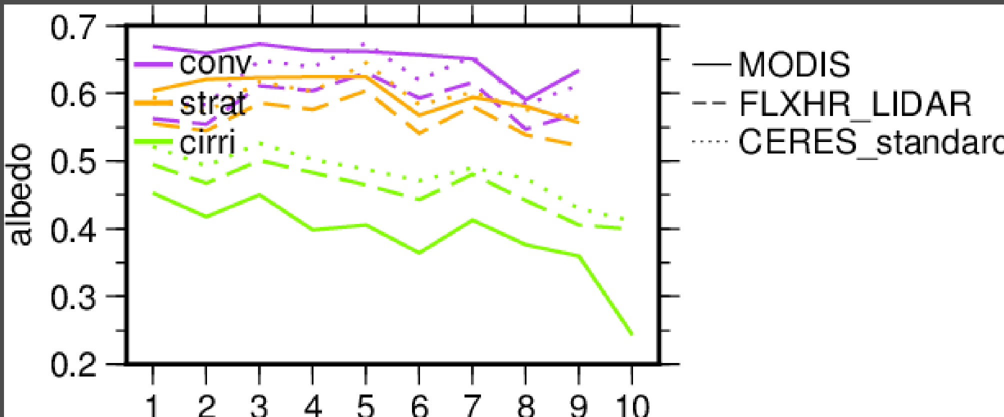
- Strong difference for the mode of the cloud top altitude between radar & lidar => small particles are present at cloud top Contribution to albedo (Jensen & DelGenio 2003)
- Decrease in cloud top faster from radar data than from lidar data.

Less difference in altitude of the mode value

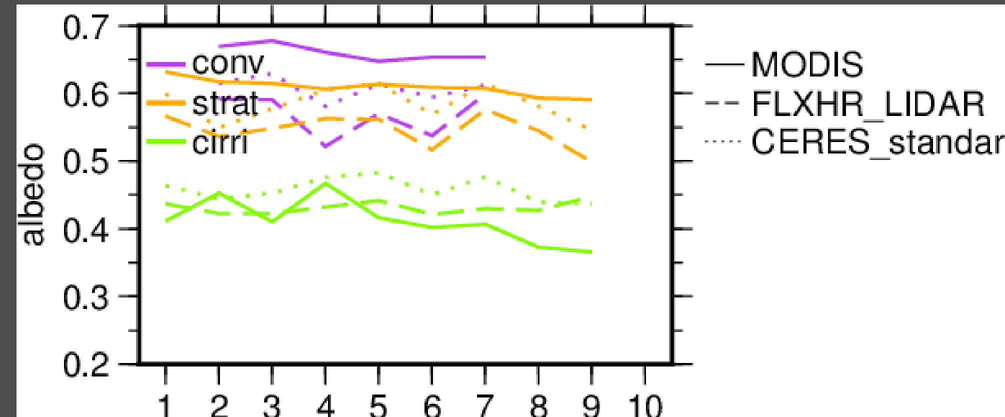


Radiative fluxes @ TOA

AF



ATL

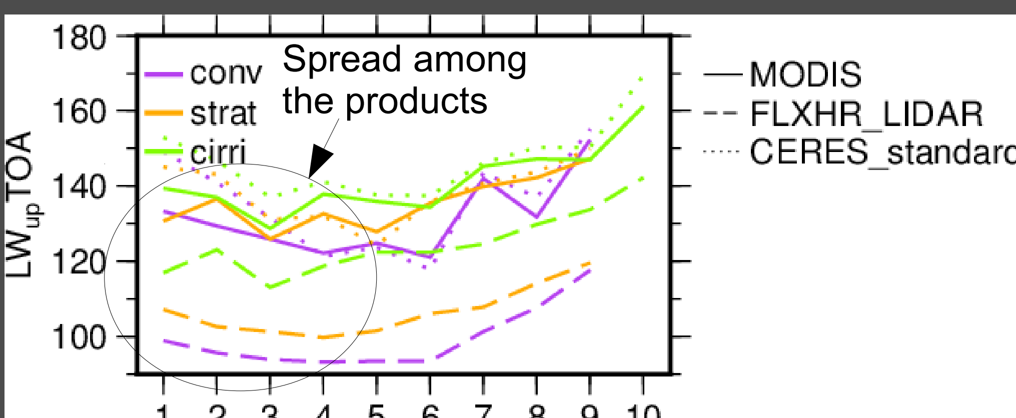


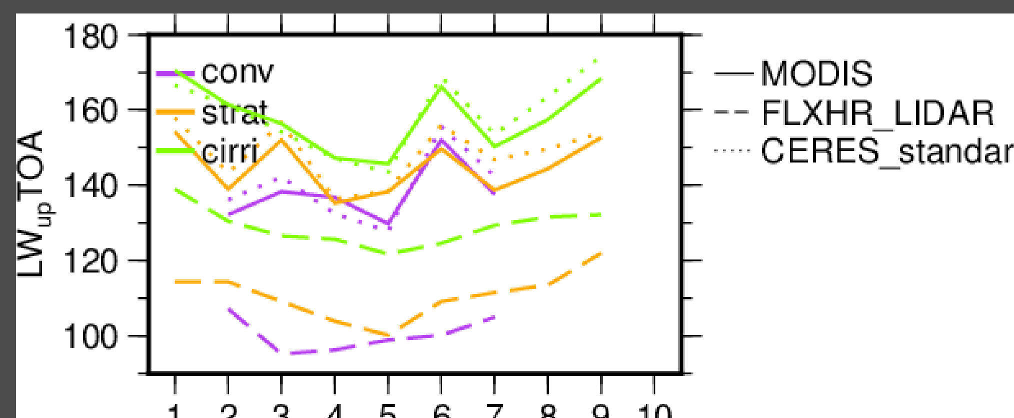
Non precipitating anvil

ATL / Less deep layer of small size crystals at the top but more cst reflectivity @ cloud base

AF / Deeper layer of small ice srystals but larger decrease in reflectivity

« Large particles in the lower parts of tropical cirrus anvils are equally important to the ice crystals near cloud top in producing high shortwave albedos. » Heymsfield & McFarqhar (1997)

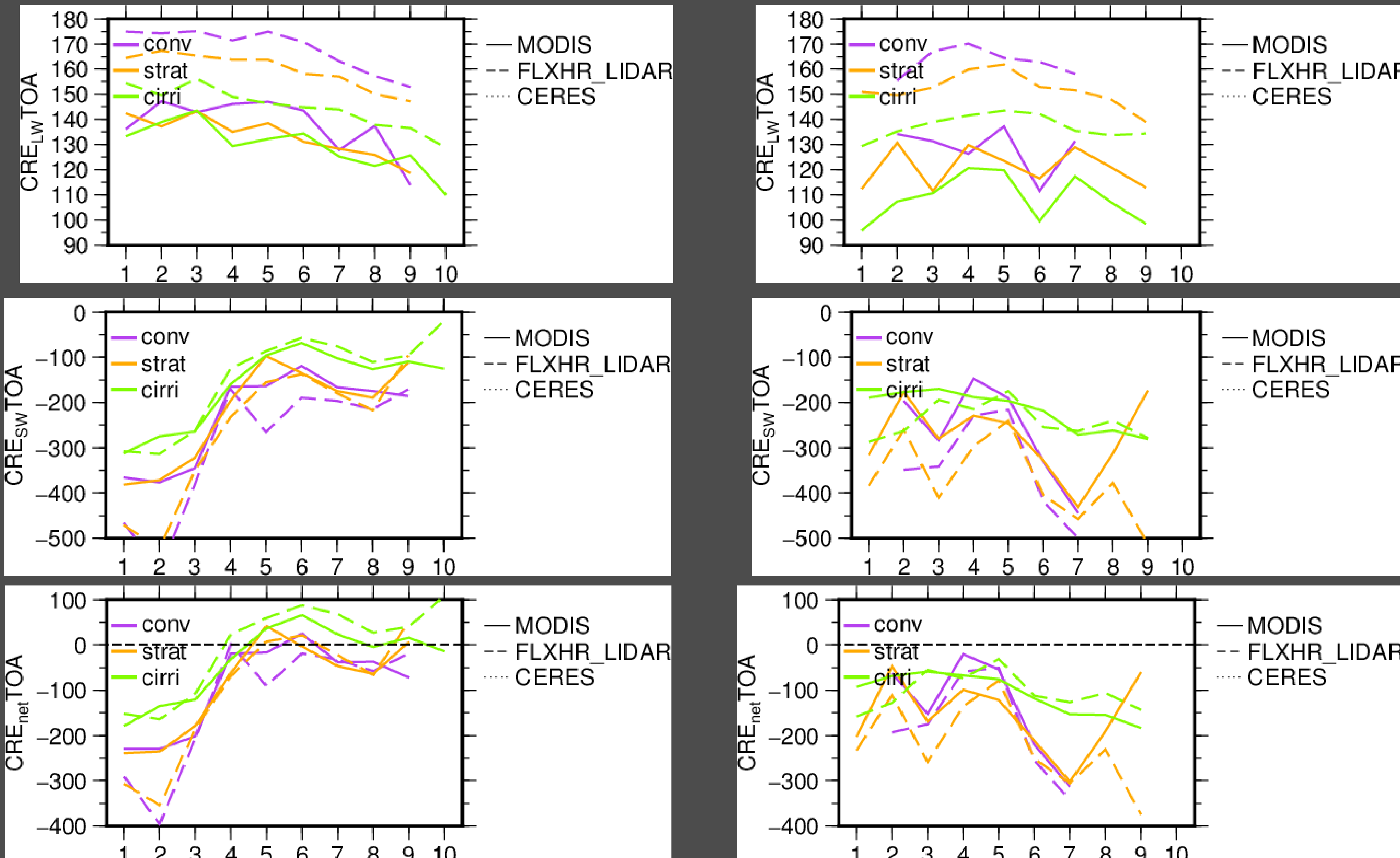




Well marked life cycle for OLR in each part of the MCS (with increase value from conv to cirri)

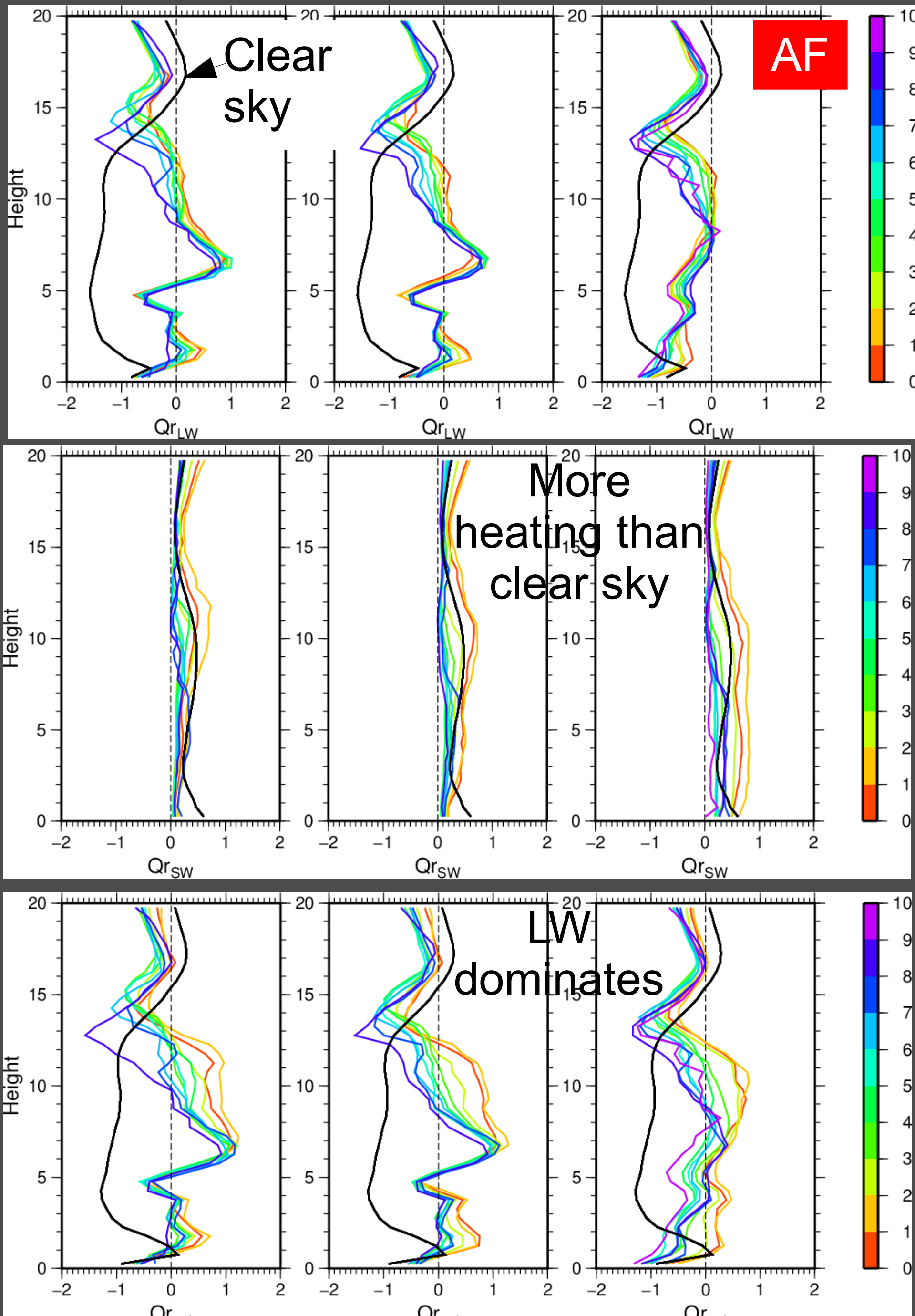
Cloud forcing @ TOA

AF ATL



Strong differences in forcing along life cycle, SW dominates, but positive forcing (LW) in AF

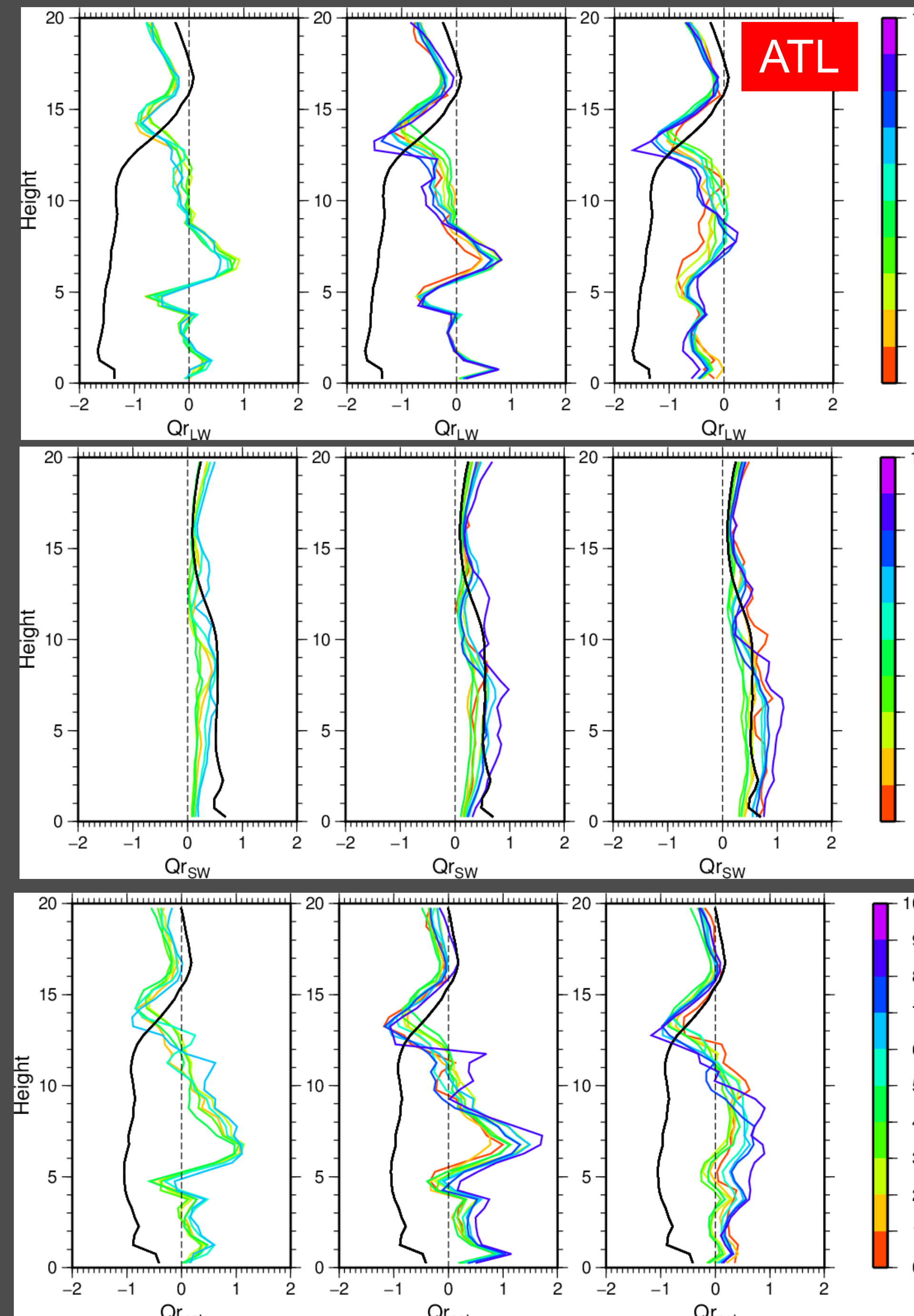
Radiative heating profiles



LW

SW

net



AF / Larger radiative heating @ beginning of the life cycle (both SW & LW)

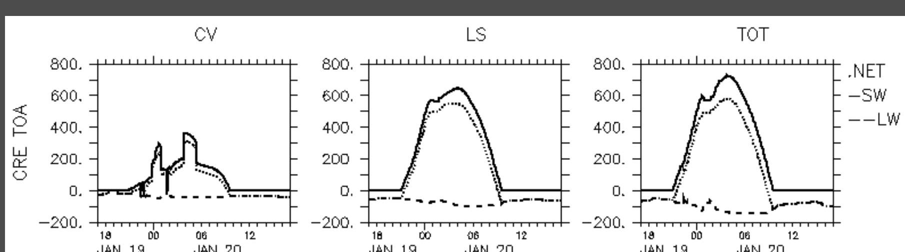
Summary

- For each geographical area composites were built according to each part of the MCS and each step of the life cycle
  Macrophysical, microphysical, radiative properties are examined

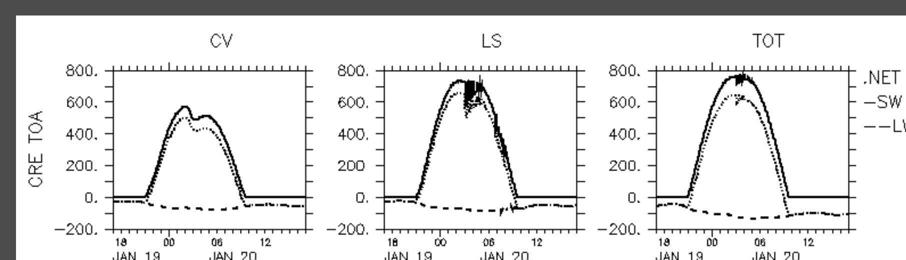
- Convection intensity differs between AF and ATL
  Life cycle is different between the two regions (from microphysical properties and prints up to the radiative heating profiles)

- How these properties combines (between various part) to lead to similar MCS life cycle in term radiation accross the geographical regions (with different scaling, Remy's talk) ?
  From these composites one can recompute the « whole » MCS properties along their life cycle assuming one knows the partitioning between conv/strat/cirri at each life step (T. Fiolleau PhD thesis)
  How these differences impact at regional scale (in particular for cloud forcing and radiative heating) ?

- Composite view usefull for evaluation and improvement of parameterization of convective processes
  Comparison of CRE @ TOA in LMDZ SCM for two physics in TWP-ICE case study



Emanuel scheme with CAPE closure



Emanuel scheme with ALP closure + cold pools

CRE change with param,larger than observed, balance between conv/strat to be investigated